

DISSOCIABLE MUSICAL PROCESSING STRATEGIES AFTER LOCALIZED BRAIN DAMAGE

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Abstract—Brain-damaged patients were asked to judge whether two familiar but lyricless musical phrases were taken from the same or from two different songs. Foils were built into the task so that patients' relative reliance on music's linear sequential properties, on its general mood characteristics, or on its susceptibility to flexible classification could be assessed. The principal results revealed that Broca's aphasics and patients with right anterior insult encountered the greatest difficulty overall in making same song/different song judgments. However, right anterior patients' musical judgments relied almost exclusively on the mood of the phrases but Broca's aphasics' judgments relied on a linear sequential musical processing strategy. These data indicate that strategies for processing musical material can be dissociated following localized cerebral insult.

INTRODUCTION

IN ORDER to assess forms of music processing after localized brain damage, subjects were asked to judge whether two highly familiar but lyricless musical phrases were taken from the same or two different songs. We hypothesized at least three strategies which could be brought to bear in listening to a song. Listeners employing the "linear sequential" strategy engage in the mental rehearsal of a song in a linear and sequential fashion which tightly parallels its public performance. They make their "same song/different song" judgments by continuing to hum the song of the first phrase mentally until the second phrase is heard. If a match or non-match is perceived between the music being hummed mentally and the music of the second phrase being heard, then the two phrases can be judged as from the same song or two different songs, respectively. If patients report that the two segments come from different pieces, however, it is also possible that they erred: segments may actually come from the same song, but patients may have hummed beyond the second phrase or may not yet have reached the second phrase in their mental humming. Since this "linear sequential" music processing strategy is highly sensitive to temporal constraints (a song is being hummed mentally as it might be performed), patients' performance should be significantly influenced by the amount of music (i.e. the length of time) which passes between two phrases taken from the same song. Consequently, patients' use of this strategy was tested by taking the two phrases of the "same song" items from relatively close portions or from comparatively distant portions of the song.

Patients employing the "labelling" strategy are able to manipulate and label a song's musical phrases independently of each other (since this strategy is not anchored to the song's

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sequential performance). They can label the first phrase with its musical source, label the second phrase with its musical source, and then compare the two labels to see whether or not they match. On the present analysis, subjects employing the "labelling" strategy should not be influenced by the different intervals between two musical phrases taken from the same song.

Subjects employing the "mood" strategy monitor general characteristics of a song such as mood. This strategy is especially valuable in the face of the impaired appreciation of pitch and/or rhythm, where the patients may be unable to hum along or identify a phrase's musical source, since "mood" is carried by a synergistic combination of musical elements. Thus, a selective deficit in just pitch or just rhythm appreciation may still spare patients' grasp of the mood of a musical phrase. According to this strategy, patients label the moods of the two phrases and then compare these mood labels. If two phrases exhibit different moods, then subjects employing the "mood" strategy should be able to determine that the phrases are from different songs. In order to test the likelihood that patients with pitch or rhythm deficits are employing the "mood" strategy, two musical phrases which were taken from different songs were selected to express the same mood in half of these items; the remainder of the "different songs" items exhibited different moods.

Previous studies have indicated that aphasics with insult to the left hemisphere can appreciate most discrete aspects of music ([1–6] also *cf.* reviews in [7–8]). Data are not available on musical processing strategies after brain damage, so specific predictions about patients' performance on our task must be inferred from the non-musical domain. Since Broca's aphasics are sensitive to serial material in non-musical domains (*cf.* [10–14]), it is possible that they may be consigned to the "linear sequential" processing strategy. Thus, they may apprehend a musical piece only in its canonical form, resulting in inferior performance on the items where the interval between phrases taken from the same song has been manipulated. Since fluent aphasics are able to access some forms of mediation [15], but they may be compromised in their ability to use covert verbal mediation [16, 17], it is possible that they may be able to employ the "labelling" strategy, at least to the extent that they can avoid using linguistic labels to tag the sources of the musical phrases. Although right hemispheric patients' compromised appreciation of discrete musical elements like pitch or rhythm [1–9] may prevent them from humming a song mentally or identifying a phrase's musical source, they may still be able to use the "mood" strategy. This would result in their inability to judge phrases as from two different songs when their moods are similar. However, an emerging body of literature [18–21] suggests that adults with right hemispheric insult are fairly insensitive to the emotional quality of information presented in linguistic and visual domains. It is possible, then, that these patients may not even be able to employ the "mood" strategy to make their judgments.

METHOD

Subjects

Twenty-four stroke patients and two neurosurgical patients with infarcts lateralized to the left hemisphere or the right hemisphere were examined in this study. Classifications were made on the basis of radiological findings (CT scan and/or radioactive brain scan) assessments on formal batteries of neuropsychological tests such as the Boston Diagnostic Aphasia Examination [22], evaluations by neurologists, and clinical findings (field cut, type of hemiplegia, hemisensory loss). Specifically, the subject population consisted of six Broca's aphasics with left anterior insult, six fluent aphasics with left temporo-parietal pathology, nine non-aphasic patients with right anterior infarcts, five non-aphasic patients with primarily right parietal insult (i.e. right posterior patients), and five neurologically-intact control subjects. The Broca's aphasics generally presented with right-sided hemiplegias, minimal indications of any sensory loss, and no evidence of visual field cuts. They exhibited effortful, agrammatic language in the context

of accurate use of contentives and clinically intact lexical semantic comprehension. The fluent aphasics did not present with hemiplegias or sensory losses, although they did generally exhibit right visual field cuts. A press of speech was characteristic of their language. Many functors were produced in the context of few contentives which were employed with modest accuracy, and clearly compromised semantic comprehension. Right anterior patients, while not aphasic, presented with left-sided hemiplegias without evidence of permanent sensory losses or field cuts. The patients with right posterior disease exhibited left-sided hemiplegias and hemisensory losses, as well as field cuts in several cases. All subjects were right-handed, 35 to 65-year-old, native English speakers. Patients with right temporo-parietal disease who met these demographic criteria and conformed to the etiological profiles of other subjects were not available for this study. None of the patients had extensive musical training, according to an interview conducted prior to testing. The chief characteristics of the patients are described in Table 1.

Table 1. Characteristics of patients who participated in this study

	Broca's/left anterior N = 6	Fluent/left posterior N = 6	Right anterior N = 9	Right posterior N = 5	Adult control N = 5
Handedness					
left	0	0	0	0	0
right	6	6	9	5	5
Age					
$\bar{X}$	55.3	51.4	54.9	55.0	53.6
range	44-65	47-55	45-63	51-57	48-63
Months post-onset					
$\bar{X}$	18.0	19.4	11.0	12.0	—
range	6-37	6-39	6-22	6-26	—
Sex					
male	4	6	7	3	4
female	2	0	2	2	1
Hemiplegia					
left	0	0	9	5	—
right	6	0	0	0	—
Hemisensory					
left	0	0	0	5	—
right	0	0	0	0	—
Field cut					
left	0	0	0	3	—
right	0	5	0	0	—
Etiology					
CVA	5	6	9	4	—
other	1	0	0	1	—

Materials

Musical stimuli were comprised of 16 items, in addition to six practice items. Each item consisted of two four-bar phrases of lyricless piano music (melody line plus accompaniment) presented on cassette tape recorder to the patients. A three second pause separated the two phrases. The songs used as sources for the stimulus phrases were judged to be highly familiar by five judges. Half of the pairs of phrases were taken from the same song, while the remainder were from two different songs. There were two conditions for the "same song" items: Under the first condition, the interval between the two phrases of the same song was four bars (thus, four bars had been omitted); for the second condition of the "same song" items, twelve bars separated the two phrases. Thus, the patients' use of the "linear sequential" processing strategy was examined by manipulating the interval between the two phrases taken from the same song. It may be noted that all of these songs exhibited essentially the same phrase structure, and the structure was such that the second phrases close to the first phrases and the second phrases at some distance from the first phrases exhibited equivalent degrees of similarity to the first phrases in terms of contour or theme. Two non-native subjects who were unfamiliar with the songs used as stimuli volunteered to take the test. Each subject felt that one of the "near" items was from a different song, although these items consisted of phrases taken from the same

song. It seems unlikely, then, that there was any overwhelming bias to judge either type of "same song" item as different. For the "different song" items, where the two phrases were taken from two entirely different songs, there were two conditions as well: for half of these items, the mood was kept constant across the two phrases (e.g. phrases from two sad songs were played); for the other half of the "different song" items, the mood differed (e.g. a phrase from a sad song and a phrase from a boisterous song were played). It is important to note here that in the "different song" condition, both phrases of a given item were played in the same key and mode, and they were associated with the same type of situation regardless of the status of the "mood" variable (e.g. two Christmas songs).

Procedure

All subjects received a training session prior to the actual testing, in order to be familiarized with each type of stimulus item and with the required set of responses. Subjects were simply asked to judge whether the two musical phrases came from the same song or two different songs. Each practice item was played twice, but if requested, practice items were replayed. Feedback on the correctness of subjects' responses during the practice session was offered. Only those subjects who clearly understood the task and were able to indicate—either verbally or by pointing—whether the phrases were from the same song or two different songs were allowed to proceed with the testing session (four patients had been eliminated from consideration since they did not understand the instructions). In the testing session, the 16 items were presented in the same quasi-random order to the subjects. Each item was played twice, after which the subject gave his response. No feedback was offered during the testing session and no items were played more than twice.

RESULTS

The patients' overall ability to judge whether two musical phrases were taken from the same song or two different songs was evaluated by a Kruskal–Wallis one-way analysis of variance. A significant difference between groups was found ($H = 18.20$; $df = 4$; $P < 0.01$). Unless otherwise stated, all subsequent comparisons were evaluated with the Mann–Whitney procedure. Assessments of patients' overall performance revealed that Broca's aphasics and patients with right anterior insult performed at significantly inferior levels in comparison to control subjects ($P < 0.005$ for both comparisons). These findings, diagrammed in Fig. 1, indicate that Broca's aphasics and right anterior patients find it difficult to judge whether two musical phrases have been taken from the same song or two different songs.

Patients' performance in judging "same song" items (i.e. items in which the "interval" foil may have interfered with patients' performance) revealed that Broca's aphasics, right

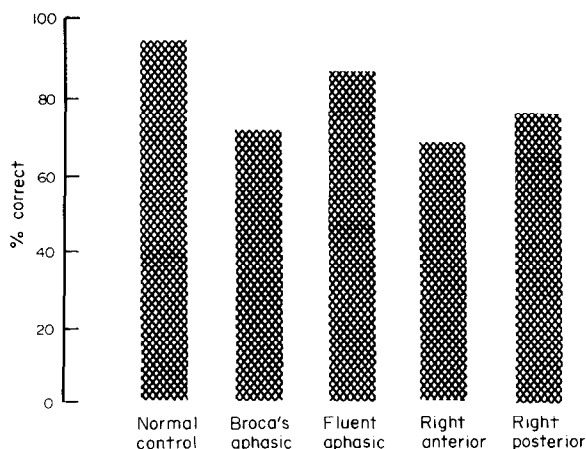


FIG. 1. Patients' overall level of accuracy at making same song/different song judgments.

anterior subjects, and right posterior patients performed at inferior levels in comparison to control subjects ($P < 0.05$ for each comparison). Further analysis of the results, however, demonstrated that only Broca's aphasics were selectively influenced by the "interval" factor. Specifically, Broca's aphasics, right anterior patients, and right posterior patients found the "close" items more difficult than control subjects and fluent aphasics ($P < 0.05$). Nevertheless, within-group comparisons of performance on items with "close" phrases vs items with "distant" phrases by the Wilcoxon matched-pairs sign test revealed that only Broca's aphasics found the "close" items significantly more difficult than the "distant" items ($T = 0.00$; $P < 0.01$). Thus, as charted in Fig. 2, Broca's aphasics were selectively influenced by the "interval" factor, since they found the "close" items more difficult than the "distant" items; the right hemispheric patients' inferior performance on the "same song" items, by comparison, may have been due to their generally depressed musical processing capacities.

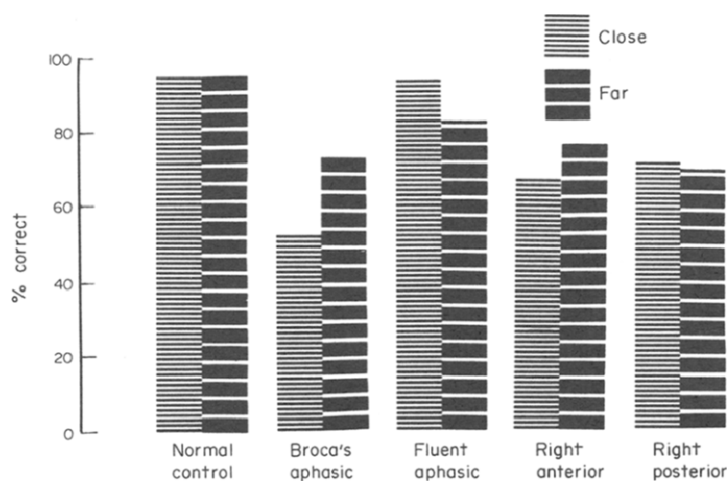


FIG. 2. Patients' ability to judge two phrases taken from the same song as a function of the interval between the phrases.

An examination of patients' performance on the "different song" items (i.e. items in which the "mood" foil may have interfered with patients' judgments) did not reveal differences between groups of patients according to the locus of insult. Further analyses, however, did demonstrate that right anterior patients performed at significantly inferior levels in their judgments of "different song" items with similar moods than control subjects ($P < 0.05$). In this context, it should be noted that all but two subjects (one Broca's aphasic and one right posterior patient) encountered as much or more difficulty determining that two phrases with similar moods were from different songs in comparison to their judgments of phrases with different moods. This is illustrated in Fig. 3. Thus, all subjects were fooled to an extent by the "mood" foil on the "different song" items. The right anterior patients may have performed at such relatively poor levels here (i.e. they were fooled to such an extent by the "mood" foil) because they have little else to rely on by way of musical processing capacity when asked to make a musical judgment, that is, other than general mood characteristics.

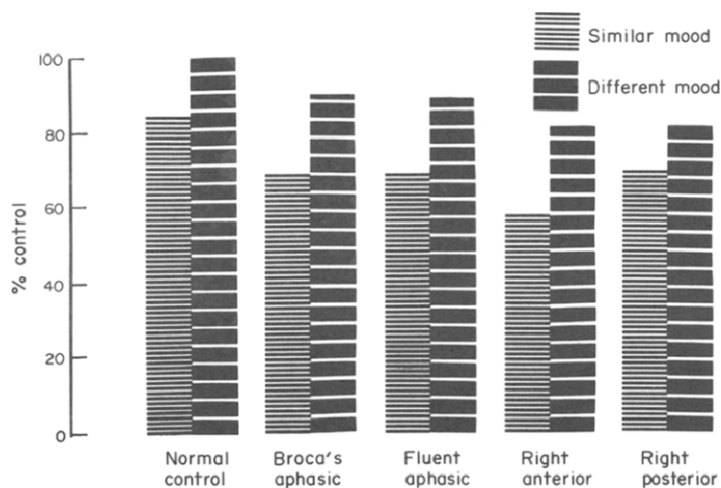


FIG. 3. Patients' ability to judge two phrases taken from different songs as a function of the moods expressed in the phrases.

DISCUSSION

The results are readily summarized. Broca's aphasics and right anterior patients encounter significant difficulty judging whether two musical phrases have been taken from the same song or two different songs. Moreover, unique performance profiles suggest that Broca's aphasics and right anterior patients may be employing different strategies to make their same song/different song judgments. Broca's aphasics appear selectively influenced by the "interval" factor, suggesting that they may process a familiar song in a linear and sequential fashion. Right anterior patients, while performing at generally inferior levels, seem to be especially influenced by the "mood" factor, suggesting that they may process a familiar song by attending almost exclusively to the emotional tone conveyed in the music, not to discrete musical elements like pitch and rhythm. Patients with insult to posterior cerebral regions apparently can tag musical phrases with their sources to varying degrees of success, and then compare these tags, as in the "labelling" strategy. Thus, there is evidence to support the claim that these forms of musical knowledge are dissociable in states of organic brain disease.

It could be argued that Broca's aphasics' selectively inferior performance on "close" items may merely be reflecting their sensitivity to musical complexity. After all, some other patients also find the "close" items more difficult than the "distant" items (although not significantly so), so judgments of the "close" items may simply be more difficult for some reason. The items with "close" phrases and "distant" phrases, however, were created so that they seemed to be of equal difficulty at an intuitive level. It should also be noted that right posterior patients and fluent aphasics find the "distant" items more difficult than the "close" items (although not significantly so), indicating that all patients do not find the "close" items more difficult. It is clear, then, that Broca's aphasics are the only patients to be selectively influenced by the "interval" factor. This suggests, according to the present analysis, that they employ a "linear sequential" processing strategy in their attempt to appreciate a familiar song.

A number of studies have indicated that right hemispheric patients encounter considerable difficulty appreciating musical material [1-8]. In fact, a recent study has found that right

anterior patients may be unable to grasp any discrete elements (e.g. pitch, rhythm) for the purpose of appreciating music [9]. It is unlikely, then, that right anterior patients are basing their "mood" judgments on a single, "tell-tale" musical attribute. In the context of this severely compromised musical processing capacity, then, it does not seem surprising that right anterior patients are highly dependent on a non-specific facet of music such as mood. In contrast to this observation stands their poor performance on other tasks requiring an appreciation of emotional tone [18–21]. It should be noted, however, that studies of mood and emotional tone have not been conducted in the musical domain. There may be some characteristic(s) of emotionality present in music but not in the visual and linguistic material which can be appreciated by right anterior patients. Alternatively, right anterior patients may be able to rely on so little specifically musical information for making their musical judgments that they are forced to extract as much general information (e.g. mood) as possible from the music. In this specific situation, right anterior patients may be capable of employing mood cues as a last resort to make a musical judgment.

Right posterior patients also performed at inferior levels on several aspects of the task. Other studies [9] have indicated that these patients encounter some difficulties processing certain aspects of music, but their deficits do not seem to be as dramatic as those of the right anterior patients. Some support for this claim may be derived from the fact that right posterior patients are less dependent on the "mood" strategy than right anterior patients (that is, they are fooled by the "mood" foil only to the same extent as the left hemispheric patients) yet still encounter some difficulty making musical judgments across the board. These patients who are not influenced disproportionately by the "interval" foil or the "mood" foil may be employing a form of the "labelling" strategy. This must be a weak form, however, since the musical processing skills preserved after right posterior insult are clearly insufficient for making musical judgments as successfully as they can be made by fluent aphasics. These aphasic patients by and large perform at superior levels on all aspects of this musical task. Indeed, their aphasia does not seem to have compromised their use of something like the "labelling" strategy. Their excellent performance underlines that an aphasia does not necessarily result in an amusia as well, just as the right hemispheric patients' inferior performance indicates that an aphasia is not a prerequisite for an amusia [8, 23].

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Résumé :

On a demandé à des patients avec lésion cérébrale, de juger si deux phrases musicales familières mais sans parole appartenaient au même ou à deux différents airs. On a construit l'épreuve de telle façon que les malades pouvaient se fier soit aux propriétés séquentielles linéaires de la musique, soit à ses caractéristiques de tonalité émotionnelle, soit à ses possibilités de classification. Les résultats principaux montraient que les aphasiques de Broca et les malades avec des lésions antérieures droites avaient les plus grandes difficultés de réaliser les jugements d'identité ou de différence. Cependant les jugements des malades avec lésions antérieures droites étaient fondés presque exclusivement sur la tonalité émotionnelle des phrases tandis que ceux des aphasiques de Broca l'étaient sur des stratégies de traitement séquentiel linéaire. Ces données indiquent que les stratégies de traitement du matériel musical peuvent être dissociées selon le siège des lésions cérébrales.

Zusammenfassung

Hirngeschädigte Patienten wurden aufgefordert zu beurteilen, ob zwei vertraute, aber nicht von Text begleitete musikalische Phrasen von demselben oder von zwei unterschiedlichen Liedern stammten. In die Aufgabe wurden Unterbrechungen in der Art eingebaut, daß es möglich war, die Strategie des Patienten in bezug auf die linearen sequentiellen Eigenschaften der Musik, ihre allgemeinen Stimmungscharakteristika oder auf die Empfindlichkeit des Patienten für flexible Klassifikation festzustellen. Die Hauptergebnisse zeigten, daß Broca-Aphasiker und Patienten mit Läsionen im vorderen Abschnitt der rechten Hemisphäre die größten Schwierigkeiten hatten, Urteile über Gleichheit oder Ungleichheit der Lieder abzugeben. Die Urteile des rechtsseitig geschädigten Patienten basierten aber fast ausschließlich auf der Stimmung der Musik, während Brocas Aphasiker sich auf die linearen und sequentiellen Eigenschaften der Musik stützten. Diese Daten zeigen, daß die Strategien für die Verarbeitung von musikalischem Material nach umschriebenen zerebralen Insulten voneinander dissoziiert werden können.